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ORIGINAL ARTICLE

Posterior decompression and fusion versus laminoplasty for cervical ossification of posterior longitudinal ligament: a systematic review and meta-analysis

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Abstract

Both posterior decompression and fusion (PDF) and laminoplasty (LAMP) have been used to treat cervical myelopathy due to multilevel ossification of posterior longitudinal ligament (OPLL). However, considerable controversy exists over the choice of the two surgical strategies. Thus, the aim of this study is to compare clinical outcomes of PDF and LAMP for treatment of cervical myelopathy due to multilevel OPLL. We searched PubMed, EMBASE and Cochrane Central Register of Controlled Trials database to identify relevant clinical studies compared with clinical outcomes of PDF and LAMP for cervical OPLL. The primary outcomes including Japanese Orthopaedic Association (JOA) score and recovery rate of JOA were evaluated, and the secondary outcomes involving visual analogue scale (VAS), cervical curvature, OPLL progression rate, complication rate, reoperation rate and surgical trauma were also evaluated using Stata software. A total of nine studies were included in the current study, involving 324 patients. The current study suggests that compared with LAMP, PDF achieves a lower OPLL progression rate, better postoperative cervical curvature and similar neurological improvement in the treatment of multilevel cervical OPLL. However, PDF has a higher complication rate, more surgical trauma and higher postoperative VAS than LAMP.

Keywords Posterior decompression and fusion · Laminoplasty · OPLL · Cervical myelopathy · Complication

Introduction

Ossification of posterior longitudinal ligament (OPLL) refers to an ectopic bone formation in spinal ligament. It often causes the compression of spinal cord due to the spinal stenosis [30]. Patients with various myelopathic symptoms due to OPLL usually require surgical intervention rather than conservative treatments. Despite a direct decompression of spinal cord has been achieved by the removal of the ossified lesion in the cervical anterior operation, it is associated with high technical criteria and life-threatening complications such as esophageal perforation and airway obstruction [8, 18, 34]. In order to

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avoid these serious complications, posterior surgery has been developed as an alternative to anterior approach.

Posterior cervical surgery is to restore spinal canal volume and relieve compression of spinal cord. It includes laminectomy, laminoplasty (LAMP) and posterior decompression and fusion (laminectomy or laminoplasty with instrumented fusion) [32]. Among these approaches, laminectomy has rarely been performed due to the absence of surgical segmental fixations. Although LAMP reserves the integrity of posterior spine structures compared with laminectomy, it is not sufficient to guarantee postoperative cervical stability and prevent kyphosis from multilevel OPLL [39], which has been confirmed in some studies [4, 11]. Conversely, Posterior decompression and fusion (PDF) achieves the goal of prevention of progressive kyphosis and maintains the stability of the cervical spine, with the reduction of cord injuries caused by re-compression of ossified lesions [4].

Previous studies have demonstrated the superiority of both PDF and LAMP in the treatment of cervical myelopathy due to OPLL [4, 10, 11, 21, 23, 41]. Of those published studies, two studies involving 86 patients (PDF = 45, LAMP = 41) suggested that PDF was more suitable for cervical OPLL [4, 21], another one study including 26 patients (PDF = 13, LAMP = 13) demonstrated that LAMP was more appropriate than PDF [11], and other three studies involving 244 patients (PDF = 143, LAMP = 101) indicated that PDF had similar clinical improvement to LAMP [10, 23, 41]. The contradictory nature of the reported studies are existed on the clinical outcomes of posterior surgery for the treatment of multilevel cervical OPLL, and it is confused for surgeons to select the optimum treatment for cervical OPLL patients. As such, the purpose of the study is to perform a systematic review and meta-analysis to compare clinical outcomes of PDF and LAMP for cervical myelopathy caused by OPLL, and to identify which procedure is a preferable technique. The primary outcomes included postoperative Japanese Orthopaedic Association (JOA) score and recovery rate. Other clinical parameters, such as visual analogue scale (VAS), C2-C7 Cobb angle, operation time, blood loss, incidence of complication and reoperation, and rate of postoperative OPLL progression, were also compared between the two groups.

Material and methods

Search strategy

Our study has been structured based on the PRISMA guidelines. Electronic search was performed using PubMed, EMBASE and Cochrane Register of Controlled Central Trials database up to 28 February 2020. In order to achieve as many potential studies (randomized control trial (RCT) or non-RCT) as possible, we used Medical Subject Heading (MSH) terms and keywords. Terms for OPLL included Ossification of Posterior Longitudinal Ligament [Mesh] OR Calcification of Posterior Longitudinal Ligament OR Posterior Longitudinal Ligament Calcification OR Posterior Longitudinal Ligament Ossification. They were combined with terms specifying surgery: ((Laminoplasty [Mesh] OR Laminoplasties OR Laminaplasty OR Laminaplasties) OR (Laminectomy [Mesh] OR Laminectomies OR Laminotomy OR Laminotomies)). Reference lists of all retrieved articles and reviews were manually searched to identify relevant studies. If necessary, we also contacted corresponding author to obtain accurate data.

Eligibility criteria

The following included criteria were applied: (1) comparing surgical outcomes between PDF and LAMP for cervical OPLL, (2) more than 18 years of age, (3) minimum 12-month follow-up, (4) English literature, (5) three or more surgical segment. Studies were excluded for following criteria: duplicate publications, case report, meta-analysis, letter, revision, review, thoracic or lumbar OPLL, technology note, commentary, animal trial and biomechanical study.

Study selection

In the original search, 698 potential publications were identified. We removed 159 duplicates and reviewed the titles and abstracts of remaining 539 publications. Five hundred twenty-five publications were excluded as following reasons: not involved PDF versus LAMP (n = 183), review (n = 83), no English (n = 12), case report (n = 96), meta-analysis (n = 11), letter (n = 12), thoracic OPLL (n = 36), technology note (n = 8), revision surgery (n = 9), commentaries (n = 10), animal study (n = 5), biomechanical (n = 5) and no related (n = 55). On basic of remaining 14 publications, a comprehensive review of full-text was performed. Two reviewers independently selected eligible literature, and any disputation was solved by discussion with a third reviewer. Finally, nine studies were included in this study [4, 12, 19, 21, 23, 24, 26, 31, 45]. The process is shown in Fig. 1.

Data extraction

Two reviewers independently extracted baseline characteristics and surgical results of included studies, with disagreements were solved by discussion with a third reviewer. The primary outcomes included postoperative JOA score (not deliberately) and recovery rate. Secondary outcomes included VAS, C2-C7 Cobb angle, occupying ratio of OPLL, operation time, blood loss, incidence of complication and reoperation, and rate of postoperative OPLL progression.

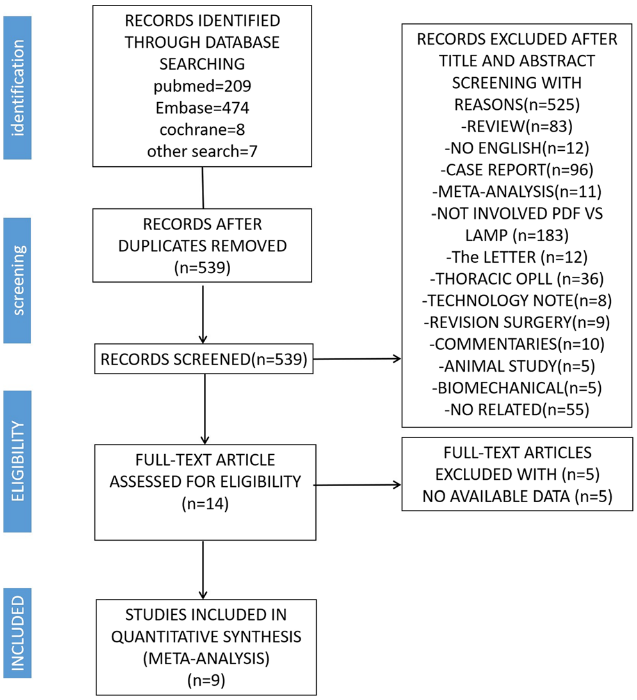

Fig. 1 The flowchart shows the process of publication selection. PDF = posterior decompression and fusion. LAMP = laminoplasty. OPLL = ossification of posterior longitudinal ligament

Quality assessment

The quality assessment of included studies was conducted using the Newcastle-Ottawa Quality Assessment Scale (NOS), as suggested by the Cochrane Non-Randomized Studies [42]. The NOS distributed a maximum of nine points for risk of bias in three parts: (1) selection of research groups (four points); (2) intergroup comparability (two points); and (3) ascertainment of exposure and outcomes (three points) for case–control and cohort studies, respectively. Study that scored six or more was qualified for meta-analysis and study that scored seven or more was considered high quality [44]. The assessment process was completed by two reviewers independently. All debates were solved by discussion with a third reviewer.

Statistical analysis

All meta-analysis was performed through Stata 14.0 software. The odds ratio (OR) and standardized mean difference (SMD) were used respectively for dichotomous outcomes and continuous outcomes, with a 95% confidence interval (CI). The I^2 statistic was used to examine the heterogeneity among studies. The heterogeneity was considered significant if P value < 0.05 or I^2 > 50%. If no obvious heterogeneity existed, the fixed effect model was selected to pool results. If present, a random effect model was utilized, and a Galbraith plot was performed to look for outliers in effect sizes. The expectation is that 95% of the studies is within the area defined by two CI lines. Then, a sensitivity analysis was performed by eliminating one or more study which was not within or far away from the area defined by two CI lines until heterogeneity was not presented, and results were compared [16]. Publication bias was formally assessed using funnel plot and Egger test (P > 0.05 suggest no significant bias).

Results

Study characteristics

Among nine included studies, one was prospective study [45] and eight were retrospective studies [4, 12, 19, 21, 23, 24, 26, 31]. All included studies were performed in Asia, three trials [4, 23, 45] were conducted in China, two were from Korea [24, 26] and four were from Japan [12, 19, 21, 31]. The sample size ranged from 10 to 83, and had a total of 324 patients (PDF group = 165, LAMP group = 159). The year of publications ranged from 2008 to 2018, and the lengths of follow-up ranged from 12 to 131 months (data not shown). The mean preoperative occupying ratio of OPLL in both groups was 45% or more. Baseline characteristic and postoperative data of included study are shown in Tables 1 and 2, respectively.

Quality assessment

Among nine included studies, one study obtained six points of NOS [12], and remaining eight studies obtained seven points of NOS or more [4, 19, 21, 23, 24, 26, 31, 45]. The quality assessment of included studies is presented in Table 3.

Preoperative JOA scores and VAS

Preoperative JOA score was available in seven studies [4, 12, 19, 21, 23, 31, 45]. No significant difference was found in mean preoperative JOA score between PDF and LAMP groups (P = 0.99, SMD = 0, 95% CI − 0.23 to 0.23), with no significant heterogeneity was identified (I^2 = 35.3%, P = 0.159, Fig. 2a). Preoperative VAS was reported in four studies [12, 23, 24, 45]. There was not a significant difference in mean preoperative VAS between two groups (P = 0.74, SMD = − 0.05, 95% CI − 0.37 to 0.26, Fig. 2b), and heterogeneity across studies was not statistical significant (I^2 = 0%, P = 0.835).

Preoperative C2-C7 Cobb angle

Preoperative C2-C7 Cobb angle was recorded in six studies [4, 12, 19, 23, 24, 26]. The mean preoperative C2-C7 Cobb angle was similar between two groups (P = 0.559, SMD = 0.17, 95% CI − 0.41 to 0.76, Fig. 2c), with significant

Table 1 Common characteristic of included studies

Study ID	Study design	Country	Surgery approach	Number of patients	Preoperative JOAs Mean ± SD	Preoperative VAS Mean ± SD	Preoperative C2-C7 Cobb angle Mean ± SD or range (°)	Preoperation occupying ratio Mean ± SD or range (%)
Hasegawa et al. 2008	Retrospective	Japan	PDF LAMP	5 5	13.2 ± 1.1 12.8 ± 1.3	4.7 ± 1.9 4.9 ± 1	− 13.6 ± 2.3 − 11.4 ± 2.4	NA
Chen et al. 2011	Retrospective	China	PDF LAMP	28 25	8.7 ± 1.6 8.5 ± 0.7	NA	6.5 ± 1.8 4.9 ± 0.7	58.2 ± 6.4 54.3 ± 4.6
Yuan et.al. 2015	Prospective	China	PDF LAMP	18 20	10.6 ± 1.1 10.6 ± 1	4.5 ± 1.1 4.8 ± 1.5	NA	NA
Katsumi et al. 2015	Retrospective	Japan	PDF LAMP	19 22	10.8 ± 3.8 10.5 ± 2.7	NA	− 1.8 ± 16.9 10.5 ± 8.7	51.5 ± 10.5 45.7 ± 13.3
Ota et al. 2016	Retrospective	Japan	PDF LAMP	27 23	7.9 ± 2.3 8.4 ± 3.1	NA	NA	NA
Lee et al. 2016	Retrospective	Korea	PDF LAMP	21 21	NA	2.9 ± 3.3* 3.4 ± 3.5	− 10 ± 11.6 − 14.2 ± 5.8	NA
Koda et al. 2016	Retrospective	Japan	PDF LAMP	17 16	7.4 ± 1.9 9.5 ± 2.6	NA	− 2.1 (− 27.6–17) 5.1 (− 16–27)	54.4 (34.1–92.7) 62.3 (43.5–90)
Liu et al. 2017	Retrospective	China	PDF LAMP	35 32	8.7 ± 1.3 8.3 ± 1.1	4.1 ± 2.8 3.8 ± 2.4	7.6 ± 1.8 7.2 ± 2.4	50 ± 11 49 ± 12
Lee et al. 2018	Retrospective	Korea	PDF LAMP	31 52	NA	NA	13.93 ± 8.46 9.43 ± 7.27	NA

NA, not available; *PDF*, posterior decompression and fusion; *LAMP*, laminoplasty; *SD*, standard deviation; *VAS*, visual analogue scale

*Significant difference

heterogeneity across studies (I^2 = 81.7%, P < 0.01). A sensitive analysis was performed by removing Chen et al [4] and Katsumi et al [19] to decrease heterogeneity (I^2 = 42.2%, P = 0.159), but statistical analysis with fixed effect model demonstrated that PDF group had larger mean preoperative C2-C7 Cobb angle than LAMP group (P = 0.02, SMD = 0.35, 95% CI 0.07 to 0.63, Appendix 1).The possible reason for instability of this result is the discrepancy of surgical indication among those institutions. Therefore, cautious interpretation should be urged.

Preoperative occupying ratio of OPLL

Preoperative occupying ratio of OPLL was available in three studies [4, 19, 23]. The higher mean preoperative occupying ratio of OPLL was found in PDF group than in LAMP group (P = 0.018, SMD = 0.38, 95% CI 0.07 to 0.69, Fig. 2d), without significant heterogeneity across studies (I^2 = 27.3%, P = 0.25).

Postoperative JOA scores

Postoperative JOA score was provided in seven studies [4, 12, 19, 21, 23, 31, 45]. The mean postoperative JOA score was similar between two groups (P = 0.99, SMD = − 0.01, 95% CI − 0.92 to 0.9, Fig. 3a), with evident significant heterogeneity across studies (I^2 = 92.2%, P < 0.01). A sensitive analysis was conducted by removing Chen et al. [4] and Ota et al. [31] to decrease heterogeneity (I^2 = 0%, P = 0.79), and statistical analysis with fixed effect model showed the stability of our results (P = 0.1, SMD = 0.24, 95% CI − 0.05 to 0.53, Appendix 2).

Postoperative VAS

Postoperative VAS score was available in four studies [12, 23, 24, 45]. Because the operative technique was decided by surgeon's preference in Lee et al. [24], which may result in high heterogeneity, we removed Lee et al. [24], and statistical analysis with fixed effect model demonstrated that PDF group achieved higher mean postoperative VAS compared with LAMP group (P < 0.01, SMD = 0.8, 95% CI 0.42 to 1.19, Fig. 3b) without heterogeneity across studies (I^2 = 0%, P = 0.97).

Postoperative C2-C7 Cobb angle

Postoperative C2-C7 Cobb angle was reported in six studies [4, 12, 19, 23, 24, 26]. The larger mean postoperative C2-C7 Cobb angle was found in PDF group compared with LAMP group (P = 0.02, SMD = 1.63, 95% CI 0.22 to 3.04, Fig. 3c), with an obvious heterogeneity across studies (I^2 = 95.8%, P < 0.01). Sensitive analysis was conducted by removing Chen et al. [4], Lee et al. [24], Katsumi et al. [19] and Lee et al.

Table 2 Postoperative data after PDF or LAMP

Study ID	Surgery approach	Postoperative JOAs Mean ± SD	Recovery rate (%) Mean ± SD	Postoperative VAS Mean ± SD	Postoperative C2-C7 Cobb angle Mean ± SD or range (°)	Complication rate (%)	Reoperation rate (%)	Blood loss (ml) Mean ± SD	Operation time (min) Mean ± SD
Hasegawa et al. 2008	PDF	14.8 ± 1.9	NA	5.7 ± 3.1	2.5 ± 4.8	40	0	178.2 ± 82.3	172 ± 47.6
	LAMP	14.6 ± 1.7		3.6 ± 2.5	− 12 ± 2.9	0	0	124 ± 50.3	92.8 ± 27.4
Chen et al. 2011	PDF	12.4 ± 1.2	43.5 ± 12.7	NA	11.7 ± 1.2	25	0	NA	NA
	LAMP	10.9 ± 0.4	25.1 ± 8.5		6.1 ± 0.6	32	0		
Katsumi et al. 2015	PDF	13.3 ± 3.6	41.6 ± 28.5	NA	− 0.6 ± 10	10.5	0	432 ± 455	240 ± 71
	LAMP	13.1 ± 3	36.1 ± 44.2		8.4 ± 10.2	13.6	0	182 ± 183	174 ± 107
Yuan et.al. 2015	PDF	13.4 ± 1.2	50.8	2.5 ± 0.8	NA	33.3	0	NA	NA
	LAMP	13.4 ± 1.5	43.7	1.7 ± 1		20	0		
Ota et al. 2016	PDF	11 ± 0.6	32.2 ± 7.1	NA	NA	11.1	NA	801 ± 185	384 ± 30
	LAMP	12.8 ± 0.7	44.3 ± 7.4			4.3		215 ± 232	187 ± 37
Lee et al. 2016	PDF	NA	NA	2 ± 2.5	− 5.1 ± 12	9.5	4.8	NA	NA
	LAMP			2.7 ± 2.8	− 8 ± 7.9	0	9.5		
Koda et al. 2016	PDF	11.4 ± 2.4	43.6 (8–77.8)	NA	− 1.3 (− 15.9–15)	11.8	0	783 ± 656.8	351 ± 101.8
	LAMP	10.3 ± 3	14.4 (− 60–66.7)		− 0.4 (− 30–23)	6.3	0	251 ± 111.3	152 ± 63.8
Liu et al. 2017	PDF	13 ± 1.5	52 ± 15.3	2.4 ± 1.6	11.9 ± 2.6	65.7	2.9	432 ± 107	147 ± 55
	LAMP	12.3 ± 1.8	46.3 ± 15.8	1.3 ± 1.2	5.6 ± 4.1	31.3	3.1	319 ± 84	114 ± 32
Lee et al. 2018	PDF	NA	NA	NA	8.07 ± 9.28	NA	NA	NA	NA
	LAMP				7.79 ± 6.71				

NA, not available; *LAMP*, laminoplasty; *SD*, standard deviation; *VAS*, visual analogue scale; *PDF*, posterior decompression and fusion; *JOAs*, Japanese Orthopaedic Association score

Table 3 Quality assessment of included studies

Study	Selection	Comparability	Outcome	Total scores
Hasegawa et al. 2008	3	1	2	6
Chen et al. 2011	3	1	3	7
Katsumi et al. 2015	3	1	3	7
Yuan et al. 2015	3	2	3	8
Ota et al. 2016	3	1	3	7
Lee et al. 2016	3	2	3	8
Koda et al. 2016	3	2	3	8
Liu et al. 2017	3	2	3	8
Lee et al. 2018	3	1	3	7

[26] to reduce heterogeneity (I^2 = 59.3%, P = 0.12), and statistical analysis with fixed effect model showed the stability of our results (P < 0.01, SMD = 1.97, 95% CI 1.41 to 2.53, Appendix 3).

Neurological recovery rate

Recovery rate was available in four studies [4, 19, 23, 31]. The mean recovery rate was at baseline between

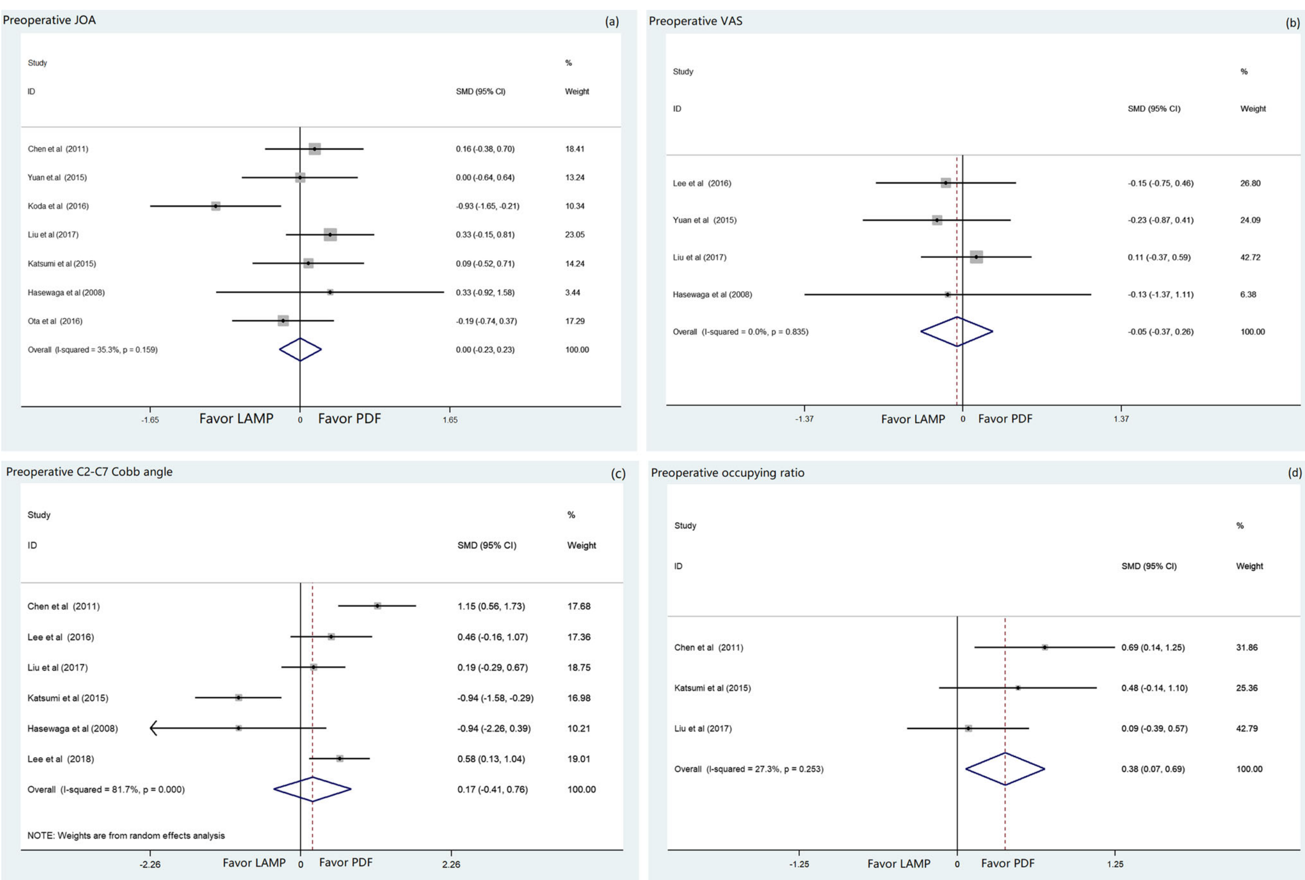

Fig. 2 **a**–**d** The forest plots show the comparison of preoperative clinical outcomes between PDF and LAMP groups. **a** The forest plot shows the comparison of preoperative JOA score between both groups. **b** The forest plot shows the comparison of preoperative VAS between two groups. **c** The forest plot shows the comparison of preoperative C2-C7 Cobb angle between both groups. **d** The forest plot shows the comparison of preoperative occupying ratio between PDF and LAMP groups. The size of the squares reflects the weight of the trial in pooled analysis. The horizontal bars represent the 95% CI. SMD = standardized mean difference. PDF = posterior decompression and fusion. LAMP = laminoplasty. JOA = Japanese Orthopaedic Association. VAS = visual analogue scale

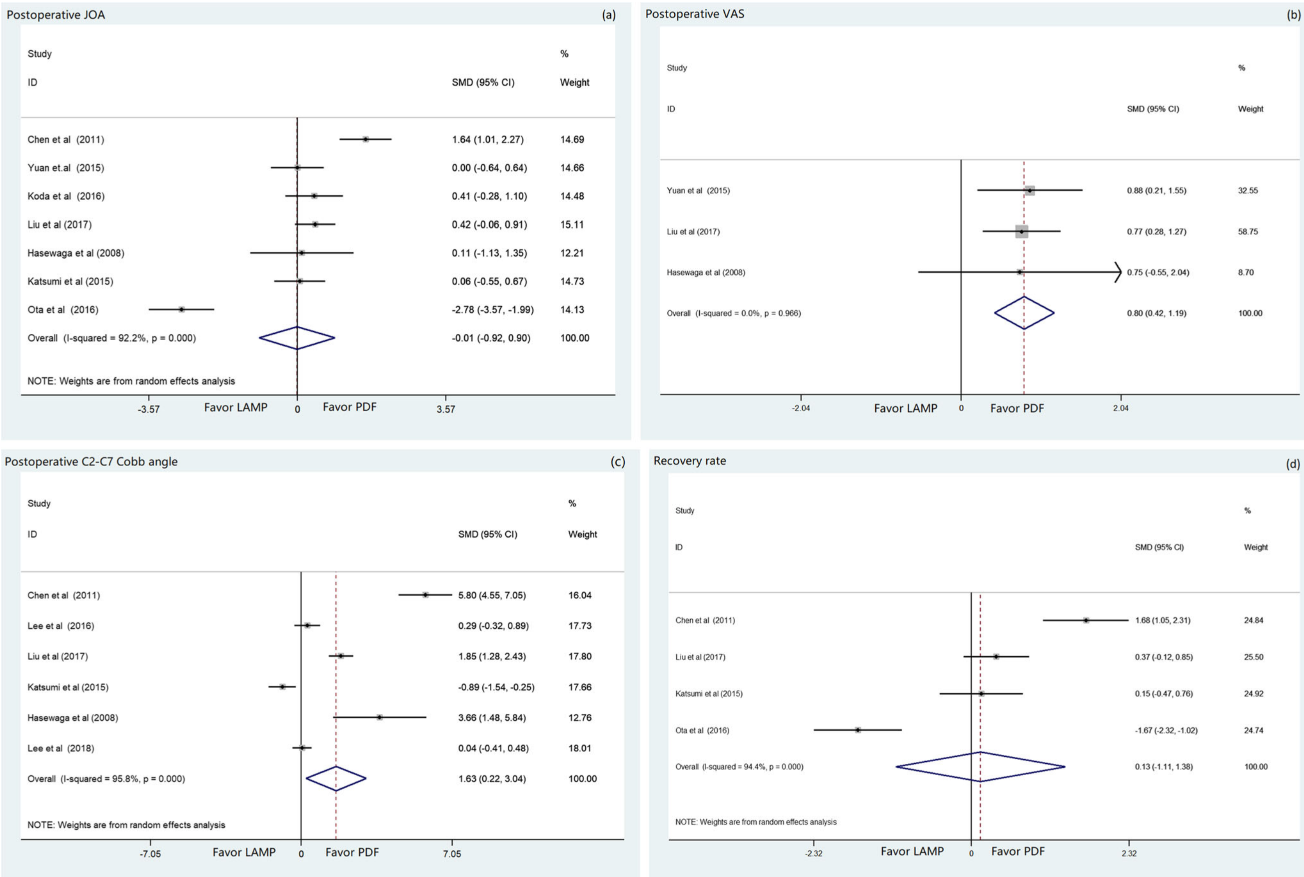

Fig. 3 **a**–**d** The forest plots show the comparison of surgical outcomes between PDF and LAMP groups. **a** The forest plot shows the comparison of postoperative JOA score between both groups. **b** The forest plot shows the comparison of postoperative VAS between two groups. **c** The forest plot shows the comparison of postoperative C2-C7 Cobb angle between both groups. **d** The forest plot shows the comparison of recovery rate between PDF and LAMP groups. The size of the squares reflects the weight of the trial in pooled analysis. The horizontal bars represent the 95% CI. SMD = standardized mean difference. PDF = posterior decompression and fusion. LAMP = laminoplasty. JOA = Japanese Orthopaedic Association. VAS = visual analogue scale

PDF and LAMP groups (P = 0.83, SMD = 0.13, 95% CI − 1.11 to 1.38, Fig. 3d), and with high heterogeneity across studies (I^2 = 94.4%, P < 0.01). Sensitive analysis was performed by removing Chen et al. [4] and Ota et al. [31] to decrease heterogeneity (I^2 = 0%, P = 0.579), and statistical analysis using fixed effect model showed the stability of our results (P = 0.15, SMD = 0.28, 95% CI − 0.1 to 0.66, Appendix 4).

Complication rate

Complication rate was available in eight studies [4, 12, 19, 21, 23, 24, 26, 45]. Compared with LAMP group, PDF group had higher complication rate (P = 0.02, OR = 2.01, 95% CI 1.12 to 3.6, Fig. 4), without evident heterogeneity (I^2 = 1.3%, P = 0.42). The distribution of complications in PDF and LAMP populations is shown in Table 4.

Reoperation rate

Reoperation rate was recorded in five studies [21, 23, 24, 45]. There was not significant difference in reoperation rate between PDF and LAMP groups (P = 0.63, OR = 0.63, 95% CI 0.1 to 4.06, Fig. 5), and the heterogeneity across studies was not statistical significant (I^2 = 0, P = 0.73).

Operation time

Operation time was available in five studies [12, 19, 21, 23, 31]. The longer mean operation time was found in PDF group than in LAMP group (P = 0.003, SMD = 2.26, 95% CI 0.79 to 3.73, Fig. 6a), with high heterogeneity across studies (I^2 = 93.5%, P < 0.01). Sensitive analysis was performed by removing Koda et al. [21] and Ota et al. [31] to reduce heterogeneity (I^2 = 19.4%, P = 0.29), and statistic analysis with fixed effect model indicated the reliability of our results (P < 0.01, SMD = 0.8, 95% CI 0.42 to 1.18, Appendix 5).

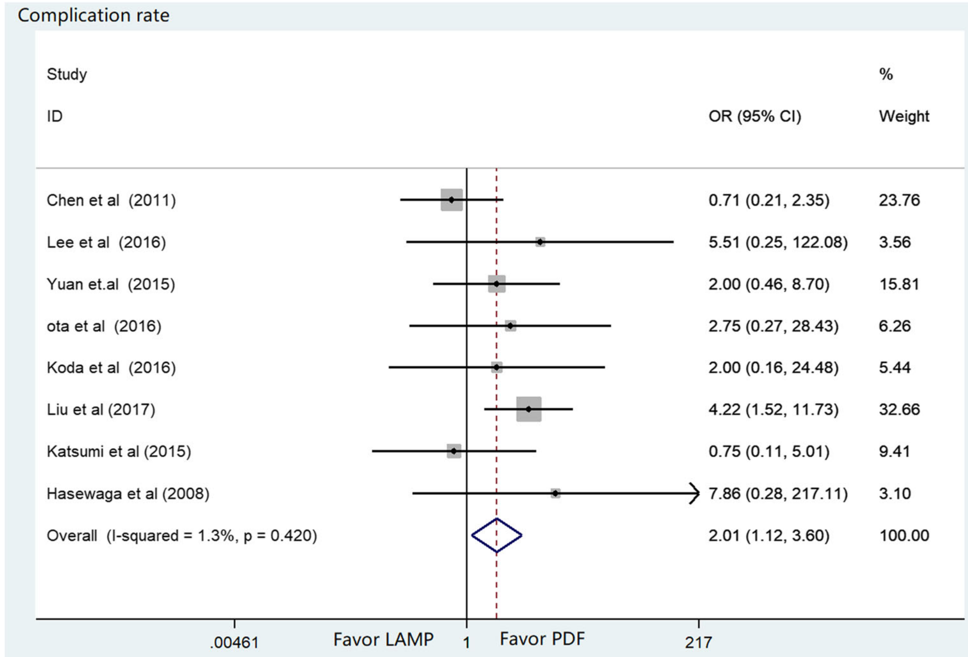

Fig. 4 The forest plot shows the comparison of complication rate between PDF and LAMP groups. The size of the squares reflects the weight of the trial in pooled analysis. The horizontal bars represent the 95% CI. OR = odds ratio. PDF = posterior decompression and fusion. LAMP = laminoplasty

Blood loss

Blood loss was available in five studies [12, 19, 21, 23, 31]. There was larger mean blood loss in PDF group than in LAMP group ($P < 0.01$, SMD = 1.34, 95% CI 0.64 to 2.04, Fig. 6b), with significant heterogeneity ($I^2 = 78\%$, $P = 0.001$). Sensitive analysis was conducted by removing Ota et al. [31] to decrease heterogeneity ($I^2 = 0$, $P = 0.75$), and statistical analysis with fixed effect model showed the stability of our results ($P < 0.01$, SMD = 1.01, 95% CI 0.67 to 1.35, Appendix 6).

OPLL progression rate

The OPLL progression rate was available in two studies [24, 31]. Due to limited number of study, systematic review was performed. The event rate of OPLL progression in PDF and LMAP groups was 22.7% (10/44) and 68.8% (33/48), respectively. Above information is presented in Supplementary Table.

Publication bias

There were fewer than 10 references to each outcome index; publication bias associated with those outcomes therefore was not properly assessed by a funnel plot asymmetry or more advanced regression-based tests [6].

Discussion

OPLL is an ectopic bone formation in spinal ligament. It usually causes spinal stenosis and compression of spinal cord. The incidence of OPLL around the world ranges from 0.1 to 4.3% [28], mainly in Asian countries. Conservation treatment may be insufficient for moderate or serious cervical OPLL; surgical treatment, therefore, is sometimes suggested [17, 29]. Although anterior direct decompression by the removal of the ossified lesions is typically used as a standard surgical strategy, it is associated with a high technical requirement and a series of complications not be ignored for multilevel cervical OPLL [8, 14]. To avoid those issues, posterior indirect decompression has been used as an effective alternative for the treatment of multilevel cervical OPLL. Among common posterior approaches, laminectomy has been the historical treatment for spinal indirect decompression [10], and LAMP and PDF are used as the reliable and effective approach in posterior surgery. Despite LAMP can achieve better preservation of cervical motion [11], the change of postoperative kyphotic alignment might hinder spinal cord shift posteriorly. PDF not only addresses the static compression of spinal cord, but also fusion eliminates the dynamic factors, hindering the progression of ossified lesion while preventing postoperative kyphosis [22]. Until now, considerable controversy exists over the choice of optimum posterior surgery for the treatment of cervical OPLL. We found that cervical OPLL patients underwent PDF or LAMP all had a good clinical efficacy, and neurological function recovery was similar between both groups. However, in view of postoperative cervical curvature and ossification progression, PDF was more preferable for individuals with cervical OPLL. Otherwise, given postoperative VAS, complication rate and surgical trauma, LAMP was superior.

Our study has several limitations. First, because there were fewer than 10 references to each outcome index, publication

Table 4 Distribution of complications in PDF and LAMP groups

Complication	PDF, no. (%)	LAMP, no. (%)
CSF leakage	2 (4.17)	0
Hematoma	1 (2.08)	2 (7.69)
Axial pain	25 (52.08)	16 (61.54)
C5 paralysis	16 (33.33)	5 (19.23)
Neurological deterioration	2 (4.17)	0
Surgical site infection	2 (4.17)	3 (11.54)
Total	48	26

CSF, cerebrospinal fluid; *LAMP*, laminoplasty; *PDF*, posterior decompression and fusion

bias was not evaluated by a funnel plot. This means that we cannot estimate whether there are smaller studies that have been conducted but have not been published. The effect of publication bias, if present, would be to influence the benefits of the PDF. Although we cannot identify this, we appeal to the readers that reasonable interpretation is recommended for clinical benefits of PDF. Meanwhile, we encourage researchers to publish their works whatever the outcomes are positive or negative to resolve this issue. Second, most of the included studies are retrospective study, which, to some extent, limits the precision of our study. Despite those included studies obtained 6 or more points of NOS, the inherent evidence defect of retrospective trial is not eliminated. Therefore, future more studies with high-quality prospective RCTs should be performed to provide more convincing and reliable guidance for clinical practice, and which would help surgeons know how to weight well the pros and cons of each procedure. Third, sample size of our study is small and the region of included studies is mainly concentrated in Asia, which might induce result biases. The possible explains are that the prevalence of OPLL is relative low, with 0.4 to 4.3% in Asia countries and 0.1 to 1.7% among North Americans and Europeans [1], and OPLL is a common cause of cervical myelopathy in Asian population, especially Japanese [7]. Thus, we appeal that more studies with multicentre, large-size and multiethnic should be performed to update our study.

Posterior laminectomy or laminoplasty and fusion ensure short and long-term stability of cervical spine, and which avoids effectively the progression of postoperative kyphosis [9, 13]. Rectification of cervical kyphosis is also an effective way for allowing a better indirect decompression from PDF, because the shift posteriorly of spinal cord is, to large content, influenced by the degree of cervical lordosis [36]. Especially when it comes to those individuals with massive cervical OPLL, PDF can eliminate the dynamic compression of ossified lesion and decrease risk of OPLL progression. On the other hand, although LAMP also provides effective indirect decompression for ossified lesion, postoperative progression of cervical kyphosis and ossified mass might cause re-compression of spinal cord and negatively impacted the long-term efficacy [15, 20, 40], because compression on

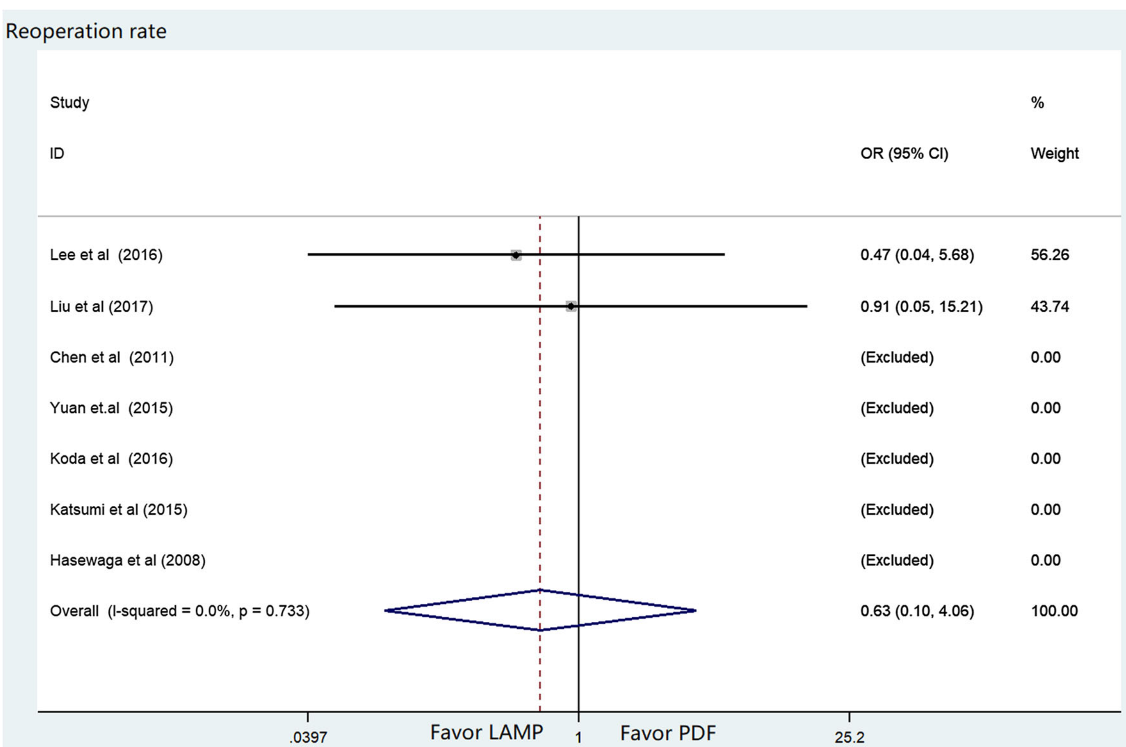

Fig. 5 The forest plot shows the comparison of reoperation rate between PDF and LAMP groups. The size of the squares reflects the weight of the trial in pooled analysis. The horizontal bars represent the 95% CI. OR = odds ratio. PDF = posterior decompression and fusion. LAMP = laminoplasty

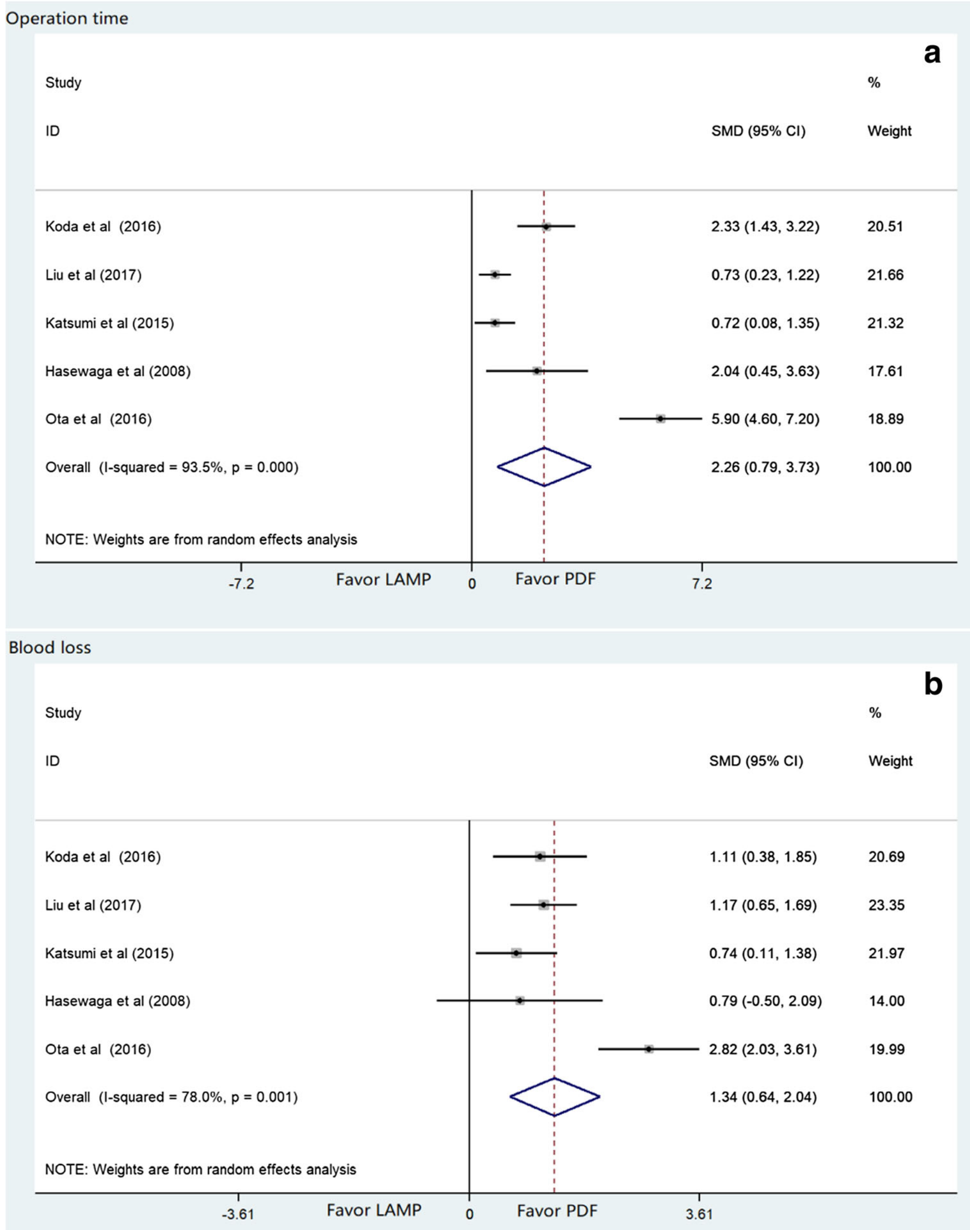

Fig. 6 **a**, **b** The forest plots show the comparison of surgical trauma between PDF and LAMP groups. **a** The forest plot shows the comparison of operation time between both groups. **b** The forest plot shows the comparison of blood loss between two groups. The size of the squares reflects the weight of the trial in pooled analysis. The horizontal bars represent the 95% CI. SMD = standardized mean difference. PDF = posterior decompression and fusion. LAMP = laminoplasty

spinal cord and small nourishing vessels from ossified lesions will increase with the loss of cervical lordosis [38]. Thus, PDF is theoretically superior to LAMP for cervical OPLL. However, we found that both groups had similar neurological function recovery after surgery. A possible reason is that PDF group has a higher preoperative occupying ratio of OPLL than LAMP group, which causes relative insufficiency of spinal cord back shift after PDF and weakens the neurological improvement [5]. Therefore, careful understanding of this is urged. In addition, laminectomy followed by fusion is associated with resection of posterior bony elements of the cervical spine, which causes a high risk of surgery-related complications and increased blood loss and operation time. Previous studies have demonstrated that compared with PDF, LAMP offered potentially lower incidence of surgery-related complications, less blood loss and shorter operation time [2, 3, 27, 43]. Our results were consistent with previous studies.

Posterior fusion surgery maintains or improves cervical alignment and prevents the development of local kyphosis deformity more efficiently compared with LAMP [4]. As shown in the present study, PDF group achieved larger postoperative C2-C7 Cobb angle than LAMP group. However, compared to LAMP, laminectomy and fusion bring more damage for posterior spinal structure and lead to increased risk of postoperative axial pain. In the present study, our results indicated that there was a higher postoperative VAS in PDF group than in LAMP group.

Posterior indirect decompression is difficult to remove ossified ligament that may progress in follow-up time. However, previous studies have indicated that instrument fusion could reduce the incidence of OPLL progression [25, 37]. Our results demonstrated that PDF group had lower incidence of OPLL progression compared with LAMP group. Although the exact mechanism with respect to the reduction of OPLL progression after instrument fusion remains unclear, mechanical stress on the hypertrophic posterior of longitudinal ligament (non-ossified) may result in progress of OPLL [33]. In PDF population, stabilization may reduce progression of OPLL owing to decreasing mechanical stimulus for OPLL. In contrast, LAMP allows for a good cervical range of motion, which increases vertebral movement, thereby inducing increased biomechanical stress and ectopic ossification of PLL. Advanced studies are needed to investigate the mechanism of OPLL progression in cases of cervical OPLL after PDF or LAMP.

To our knowledge, the prevalence of OPLL in Asian countries is reported to be 0.4 to 4.3%, while the incidence is estimated to be 0.1 to 1.7% among North Americans and Europeans [1]. OPLL mostly occurs in the cervical spine and is a common cause of cervical myelopathy in Asian population, especially Japanese [7]. Although there are some other scores for the function of spinal cord such as Frankel and Nurick scores, Frankel score has seldom been used due to the lack of rigour, and Nurick score could not accurately assess upper limb function. Compared to above two scores, JOA score not only reflects the function of spinal cord comprehensively, but also is simple and practice [35]. Those could explain why many researchers employed JOA score as the standard for evaluations. Furthermore, JOA score has been modified, for example, changing "ability to use chopsticks" into "ability to write." This makes JOA score applicable to both easterners and westerners, and further reduces the analysis result biases from regional difference.

This study is the use of statistical methods to summarize and combine the results of independent studies, and a key benefit of this approach is the aggregation of information leading to a higher statistical power. Furthermore, it provides a comprehensive evaluation for clinical practice. However, there are no enough large-size RCTs comparing the clinical outcomes of each operation for treatment of cervical OPLL. Thus, future study with long follow-up time, large-sample and high-quality RCTs should be performed to provide more convincing and reliable guidance for surgeons in treatment of cervical OPLL.

Conclusion

Our systematic review and meta-analysis reveal that for cases of multilevel cervical OPLL, PDF achieves a lower incidence of OPLL progression, better postoperative cervical alignment and similar neurological improvement compared with LAMP. However, PDF has a higher rate of complication, higher postoperative VAS and larger surgical trauma than LAMP.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval Ethical approval not applicable as this is a systematic review and meta-analysis.

Informed consent This is a systematic review and meta-analysis so for this type of study informed consent is not applicable.

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